Shifting sands

New technology has turned oil sands in Canada, the world's largest oil sands producer, into a source for titanium minerals. Michael Forrest spoke to the Titanium Corporation about how an oil producing waste stream can provide new resources for a growing industry.

Oil sands, once the poor relation of the oil industry, are today proving to be more profitable than previously imagined. Oil recovery and concentration of heavy minerals provide a suitable feedstock for recovery of heavy minerals such as titanium and zircon, and companies with experience in a combination of oil sands processing and heavy mineral recovery will be cashing in, in the next few years.

The titanium-bearing minerals market stands at around 7.25 million metric tonnes annually. Titanium feedstock and associated products are worth US$2 billion a year, and total annual sales for the titanium dioxide and titanium metal markets are approximately US$9 billion, based on the seven-year research programme of the Titanium Corporation.

Over the past 25 years, demand for titamium has grown by about 3% per annum, with North America and Western Europe accounting for approximately 40% and 30% of global demand respectively. This level of growth is expected to continue and is driven by expansion in numerous end markets from aerospace to plastic bottles.

Importantly, there are no ready substitutes for titanium metal and titanium dioxide in pigments, the latter of which accounts for about 95% of the titanium sold in concentrates. 'This is a good market for any producer,' says Titanium Corporation company Chairman and CEO, George Elliot. 'Growth is steady and predictable, the ratio of capital cost

Oil sand tailings containing valuable titanium-bearing minerals and zircon

Lake Mildred oil stream tailings

Mineral	% (weight)
Ilmenite	25.3
Leucoxene	30.7
Rutile	2.3
Anatase	1.6
Zircon	6.3
Garnet	3.0
Kyanite	7.5
Tourmaline	13.2
Pyrite	4.9
Siderite	3.3
Other HM	1.9
Total	100.0

Mineralogical Analysis by Geochempet Services, Australia

to income is better than most other mined commodities, and most of the production is not recyclable.'

The waste stream from oil sands also contains significant quantities of zircon, a refractory mineral used in ceramics glazes that account for 60% of consumption of the mineral. 'The supply and demand balance for zircon is currently very tight and demand is expected to outstrip supply for the foreseeable future, driven primarily by heavy demand from the rapidly growing Chinese ceramic and TV glass industries,' Elliot explains.

In 2002, the supply of zircon increased by 3.8% which was insufficient to meet the strong level of demand, causing an estimated 5,000t deficit against production of roughly 1.1Mt in that year. As a result, the price of zircon has increased from US$299/t in 2000 to approximately US$400/t today. Further price increases are forecast through the 2005 driven by the growing imbalance expected between supply and demand.

Recovery research

Over the past decade research by the Titanium Corporation has focussed on developing a method of recovering heavy minerals from oil consortium Syncrude's oil sand industry (see box – Oil sand reserves in Canada). Initial research indicated that the process stream for oil recovery contained sand grains rich in titanium and other heavy minerals.

Syncrude had known of this preferential affinity for heavy minerals – particularly titanium minerals and zircon – with bitumen for some time. Research for the Titanium Corporation by Cyril Cole at the Minerals Engineering Centre, Dalhousie University, Halifax, Nova Scotia, confirmed that the centrifuge plant tailings from the oil sand operations contained between 20% to 50% heavy minerals, 10 times greater than alluvial deposits worked commercially in Australia and Africa.

Leucoxene, a titanium mineral, contains the highest titanium concentrations at up to 80% TiO_2. Strictly speaking an alteration product, leucoxene is abundant in the Athabasca oil sands due to their oxidised state and unique geological history.

Although the high heavy mineral content in centrifuge plant tailings from the oil sands operations had long been known, there were a number of barriers to their development. Firstly, Syncrude is an oil producer, and its expertise is in mining and oil recovery, not mineral processing. Secondly, the waste stream from oil recovery, although containing high heavy mineral concentrations, is coated in bitumen, which most titanium producers would find unacceptable. To solve the problem, experience in both heavy mineral and oil sands processing was required.

Lake Mildred (Image: Syncrude Canada Ltd)

Oil sand reserves in Canada

Canada's oil sands have 175 billion barrels of proven reserves and around another 140 billion of probable reserves, well ahead of those in Iraq. The largest of these resources occur in the Athabasca Oil sands in Alberta covering over 30,000km² and estimated to contain 1.8 trillion barrels.

The Athabasca basin that contains the oil sands extends over an area greater than Lake Ontario and has been the focus of Syncrude's (a consortium of oil companies) operations since the 1970s. The 130-million-year-old deposits consist of sand, clay, water and bitumen and can be seen in outcrops along the lower Athabasca River in northeastern Alberta, overlying Devonian limestone of the Beaverhill lake group. They are capped by marine clays of the Clearwater Formation, which probably accounts for their preservation.

Like most sand deposits, the principal Athabasca minerals are silicates – primarily quartz. In addition, the oil sands contain heavy minerals including titanium minerals and zircon. Average concentrations in sand deposits are around 2-4%, (see *Materials World*, February 2004, pp8-9). but the oil sands contain only 0.25% or less. Mining of the deposit for titanium and other heavy minerals would be uneconomic without the oil recovery and the concentration of the heavy minerals that occurs along with it, and the heavy bituminous coatings on the mineral from which the oil is obtained posed a logistical problem for mineral recovery. In the past, both of these were major factors in preventing any downstream processing of heavy minerals from the Athabasca sands, but today new techniques have made recovery a viable option.

Recovery of the oil from the oil sands at Syncrude is a round the clock operation that begins with shovel and trucks that recover some 20,000t/hour from Syncrude's Mildred Lake and Aurora mines, 40km north of Fort McMurray. These sands produce 250,000 barrels of oil per day, which is estimated to increase 350,000 barrels of oil per day in two years. Cash costs are in the region of CAN$18 per barrel – comparable to crude oil if discovery costs are factored into the equation, says Syncrude.

About 90% of the bitumen in the oil sands is recovered into a concentrate in Syncrude's extraction process. This concentrate contains about 10% solids that form the feedstock for the heavy mineral recovery operation. Downstream bitumen processing, including cracking, hydrogenation and fractionation, results in a high-grade sweet (low sulphur) product.

Spirals separate different density minerals using centrifugal force (left). Oil sand mining uses large-scale shovels and trucks (right)

Pigment, pilots and patents

The challenge was to produce a concentrate from the oil process stream. Formerly Manager for Research Programs at Syncrude, John Oxenford, Titanium Corporation's senior Vice President, brought his experience in oil sand processing to the project. Over the past three years, Titanium Corporation has integrated conventional oil sands technologies with those related to heavy mineral sands separation in its laboratory facilities at Dalhousie University, which has resulted in a simplified process to make marketable titanium and zircon products from this rich tailings stream.

The company currently has a CAN$10 million, 5t/day pilot plant operating at the Saskatchewan Research Council's (SRC) facility in Regina, Canada. The SRC has a 25-year history of research for Syncrude and other oil sand developers. The first phase of processing, known as the wet gravity phase, removes bitumen using the Titanium Corporation's patented process. Once cleaned, the sand is passed through standard gravity concentration equipment, such as spirals, to separate the minerals. The target is to produce a concentrate of more than 80% total heavy mineral at a 75% recovery rate, to be verified by mass-balance calculations and independent mineralogical assays.

The second phase of processing, known as the dry phase, begins with drying the wet concentrate and then using electrostatic and magnetic separation techniques to separate the minerals based on their different properties. Ilmenite, for instance, is magnetic and a conductor. High titanium content rutile and leucoxene is weakly magnetic and weakly conductive. Zircon is non-conductive and non-magnetic.

These trials are set to make Titanium Corporation a major player in the titanium minerals industry. According to Elliot, the project has a number of advantages over existing producers. 'Firstly, as the feed to our plant is Syncrude's waste, it has no effect on their operations and involves no mining costs to Titanium Corporation. Secondly, it may be possible to recover bitumen from this stream adding cash flow to the project,' he says. Another advantage is that our waste stream enters the Syncrude environmentally engineered tailings system,' Elliot adds, 'saving the company the costs of tailings disposal, which added to an estimated 100-year mine life adds stability, not to mention very low production costs.'

Titanium Corporation has filed applications with the US Patent and Trade Mark office and with the Canadian Intellectual Proprietary Office, and patents are pending that broadly cover the entire process required to create marketable products. A major pigment manufacturer was introduced to the project to ensure that the final product was acceptable and fully integrated into the pigment industry, and Titanium Corporation hopes to have full commercial use of Syncrude material by 2008. Planned production from the waste stream will account for 5-8% of world demand, and this could all be consumed by the pigment partner.

Today's lucrative oil sands industry is far from being a poor relation to the oil industry. With forecasts of strong growth in the global demand for titanium, they may yet have the potential to significantly add to the world

Author's details

Michael Forrest is the minerals and mining Commissioning Editor for *Materials World* and can be contacted via e-mail: michael.forrest@miningresearch.co.uk.

For further information about the Titanium Corporation, visit www.titaniumcorporation.com.